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Technical News

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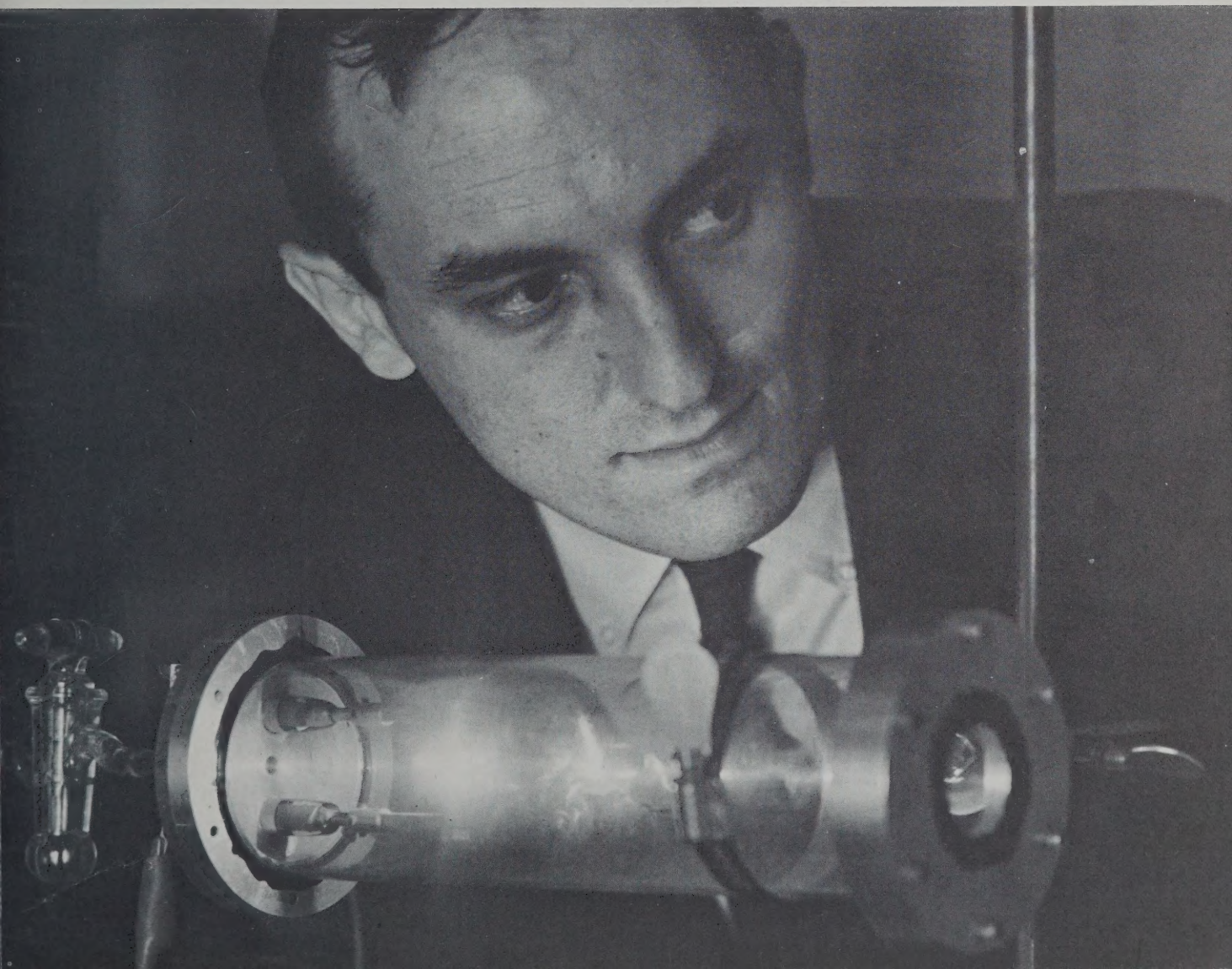

U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

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Contents

Page

Atomic spectroscopy 141

Interpretation of rare-earth spectra simplified by light source giving self-reversed lines 141

Experimental transition probabilities for spectral lines of 70 elements 143

Photocomposition by computer program gives high-quality typography semiautomatically 145

Mercury 198 lines as secondary length standards 146

Calculated germanium vacuum ultraviolet wavelength standards . 147

NBS hydrocarbon standard materials transferred to American Petroleum Institute 148

Electron-optical image of a pulsed atomic beam 149

NBS holds seminar on mass measurement 152

IRE Microwave Group symposium 153

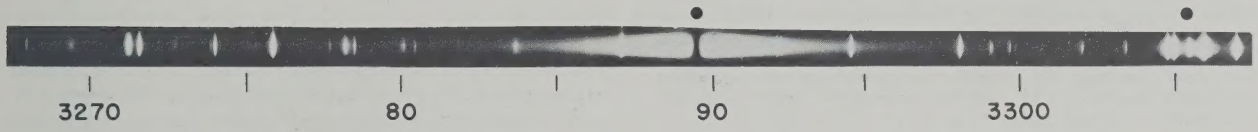
Publications of the National Bureau of Standards 154

COVER: Jack Sugar positions the pulsed high-current d-c arc light source that he developed for use in the production of spectrograms containing highly self-reversed lines. Such lines aid in the interpretation of complex rare-earth spectra. (See "Interpretation of Rare-Earth Spectra Simplified," p. 141.)

Atomic Spectroscopy

The use of spectral analysis to study atomic structure has led to a theoretical understanding of the periodic system of the elements and to such important discoveries as electron spin. This productive technique is employed in the Bureau's atomic spectroscopy laboratory to determine some of the important characteristics of atoms—their energy level structures, the probabilities of transitions among these discrete energy levels, and the wavelengths of light emitted during such transitions. Related to these studies are efforts to originate or adapt needed items of equipment, such as light sources that will permit the desired internal consistency among wavelength determinations over a wide range of wavelength values, and to utilize such equipment so as to improve and refine available measurements and methods.

Some of the current research and development in atomic spectroscopy at the Bureau is presented in the following group of five articles. Although typical, the work reported here by no means represents the entire scope of the Bureau's efforts in this area. These articles do, however, discuss some of the more important aspects of the work—establishment of wavelength standards, analysis of unknown spectra, and determination of atomic transition probabilities.



Interpretation of Rare-Earth Spectra Simplified

by Light Source Giving Self-Reversed Lines

A LIGHT SOURCE which produces numerous self-reversed lines in the spectra of both neutral and singly ionized rare-earth elements—thereby simplifying their interpretation—has been developed by Jack Sugar of the spectroscopy laboratory. The source [1] is a pulsed arc discharge with a peak current of 75 amp and an on-time of 1 msec per cycle.

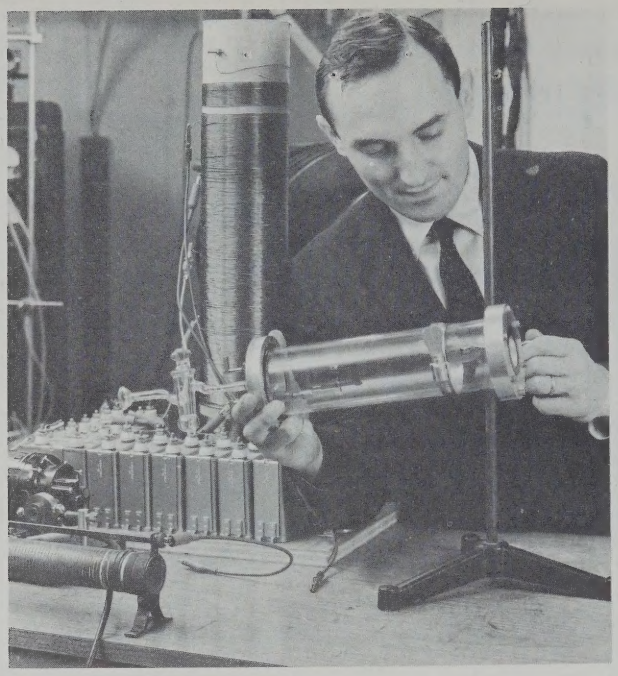
In this source, the self-reversal of lines arising from transitions to the ground state of the atom is so severe that such lines are easily recognized. Studies of these lines reveal the nature of the ground state of the atom. Thus, spectrograms obtained in initial investigations with the source quickly led to the interpretation of the ground states of neutral terbium and singly ionized uranium, and to the verification of the reported ground states of neutral uranium and both neutral and singly ionized ytterbium and thulium.

Above: **Spectrogram of ytterbium obtained using the pulsed high-current d-c arc light source. The source produces numerous highly self-reversed lines in the spectra of both neutral and singly ionized atoms of rare-earth elements. Self-reversed lines are indicated by dots.**

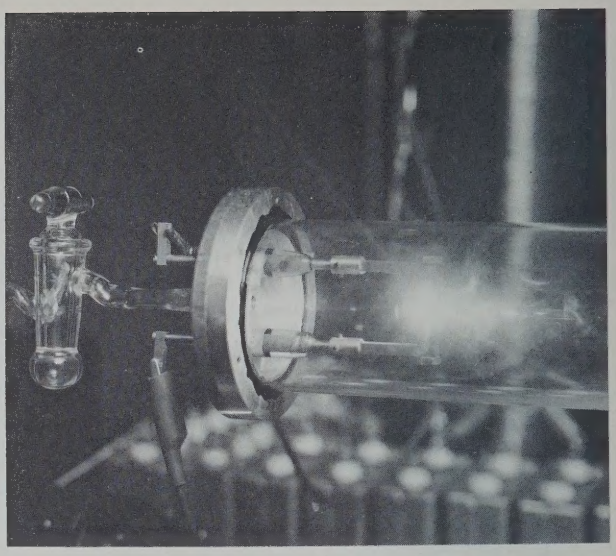
A self-reversed spectral line is characterized by a decrease in the intensity of radiation at its center, where normally the intensity is a maximum. This unusual intensity distribution results when the spectral radiation produced by a hot vapor passes through a cooler vapor of the same kind of atoms, many of which are in the final energy state to which the radiating atoms decay. The cooler atoms absorb the radiation, reducing the strength of the spectral line. Maximum absorption occurs at the center of the line because of the dependence of self-reversal on the initial intensity of the radiation and on the absorption line shape.

At least three different light sources containing such a distribution of atoms have been used in the past—the high-temperature furnace, the underwater spark, and the d-c arc. However, difficulties are encountered with each of these sources.

The furnace consists of an electrically heated carbon tube containing metallic vapor through which a light continuum is passed. Absorption lines are produced in the continuum which correspond to self-reversed lines in the emission spectrum of the vapor.



Jack Sugar prepares to use the pulsed high-current d-c arc light source. At left are the components of the circuit containing a delay line which produces a high peak current of 75 amp lasting 1 msec, while maintaining a low average current. These components are (*clockwise*): the load resistor, the current interrupting arrangement (rotating spark gap), and the capacitive and inductive components of the delay line.



Pulsed high-current d-c arc for the production of highly self-reversed spectral lines. This simple light source was developed to produce spectrograms that would aid scientists in their interpretations of the complex spectra of rare-earth elements.

However, only very low-lying energy levels of the neutral atom—and, usually, no ionic levels—are sufficiently populated in the furnace vapor to produce absorption lines. Furthermore, metals with very high boiling points do not sublime in the furnace.

The underwater spark produces a continuum containing absorption lines similar to those in the furnace vapor. It has been used successfully to obtain the absorption spectra of many elements, but it failed to give a single absorption line when operated with uranium electrodes.[2] Presumably, this failure occurred because uranium is readily oxidized, as are most rare-earth elements. The operation of the pulsed arc in an inert atmosphere of helium prevents the loss of metallic vapor due to oxidation.

An arc discharge consists of a hot central radiating plasma surrounded by a sheath of cooler vapor; hence, it nearly always produces self-reversal of the very strong lines in the neutral and ionic spectra of the electrode material. Because almost all rare-earth spectral lines are of low intensity, however, self-reversal of these lines rarely occurs in an ordinary low-current arc discharge.

The degree of self-reversal increases exponentially with the product of the intensity of the radiation and the density of absorbing atoms in the cooler vapor. Raising the current in the arc increases the rate of vapor production and therefore the density of absorbing atoms, so that self-reversal is enhanced. A substantial rise in current, however, requires an elaborate cooling arrangement to prevent melting of the electrodes.

The light source developed by the Bureau is a pulsed d-c arc that provides a high peak current for producing a high vapor density, while maintaining a low average current which keeps the electrodes from melting. The pulsing is obtained by discharging a delay line across the arc gap, which is immersed in helium at a pressure of 1 atm. The resulting current waveform is a square pulse having a width and height that can be adjusted by varying the parameters of the delay line. In this work, a width of 1 msec and a height of 75 amp were used.

The cool, absorbing vapor layer surrounding the discharge contains mostly neutral and singly ionized atoms in their ground state or nearby states. Therefore, practically all the self-reversed lines arise from transitions to these low-lying energy states. Herein lies the value of self-reversal in the interpretation of spectra: From the thousands or sometimes tens of thousands of spectral lines obtained with rare-earth elements, several hundred may be selected that are known, because of their self-reversal, to result from transitions to low-lying energy levels. By searching for repeating intervals among these selected lines, one may more easily deduce this portion of the atom's energy level structure.

The pulsed arc produces such severe self-reversal of resonance lines (lines arising from transitions to the ground state of the atom) that these lines usually are easily recognized. The dark space resulting from absorption at the center of a resonance line is very wide—sometimes so wide that the original radiation is almost completely removed. By studying the structure

of resonance lines in a magnetic field, one can deduce the quantum numbers of the ground state of the atom. Furthermore, if such lines have not been taken into account in an energy level scheme, the scheme probably does not include the ground state.

Finally, the relative degree of self-reversal of lines of equal intensity is a valuable clue to the determination of the relative positions of energy levels, for, as previously mentioned, self-reversal depends on the product of the radiation intensity and the number of absorbing atoms. The second factor decreases exponentially with the height of the absorbing energy level above the ground state.

While spectra of rare-earth elements can be interpreted without the aid of self-reversed lines, their presence makes possible the use of many simplifying techniques.

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[1] *For further details, see* Light source for producing self-reversed spectral lines, *by Jack Sugar, J. Research NBS* **66A** *(Phys. & Chem.), No. 4, 321–324 (1962).*

[2] C. C. Kiess, C. J. Humphreys, and D. D. Laun, *J. Research NBS* **37**, *No. 1, (1940) RP1729.*

Experimental Transition Probabilities for Spectral Lines of 70 Elements

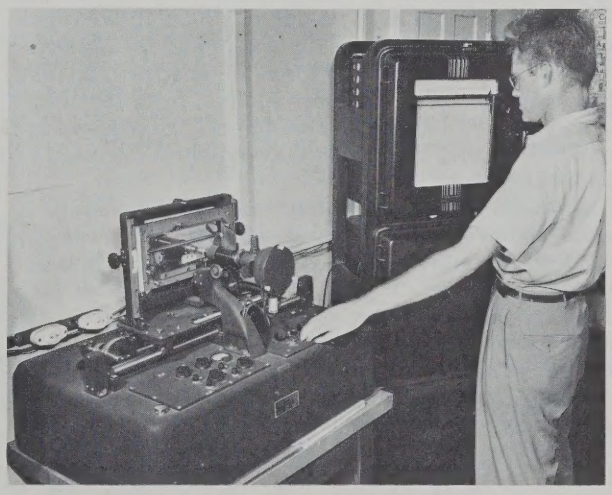
APPROXIMATELY 25,000 experimental transition probabilities (gA), or oscillator strengths (gf), for spectral lines of 70 elements have been derived by C. H. Corliss and W. R. Bozman. This work [1] has increased the number of known transition probabilities for these elements by a factor of 10. The wavelength range of the lines included in the study is from 2000 to 9000 A. More than half the lines are from spectra of elements for which there were no previously known transition probabilities. About two-thirds of the lines are from spectra of neutral atoms, and one-third are from spectra of singly ionized atoms.

The results are expressed on a uniform absolute scale, so that in the analysis of stellar atmospheres, for example, absolute quantities of constituents can be determined. To illustrate the utility of these transition probability values in such practical astrophysical work, Mr. Corliss has used them to construct a curve of growth for the second spectrum of yttrium in the sun. Values from the tables have been used in industrial laboratories to measure temperatures of plasma jets. They also are useful in determining temperatures of stellar atmospheres and of laboratory light sources that emit atomic spectra.

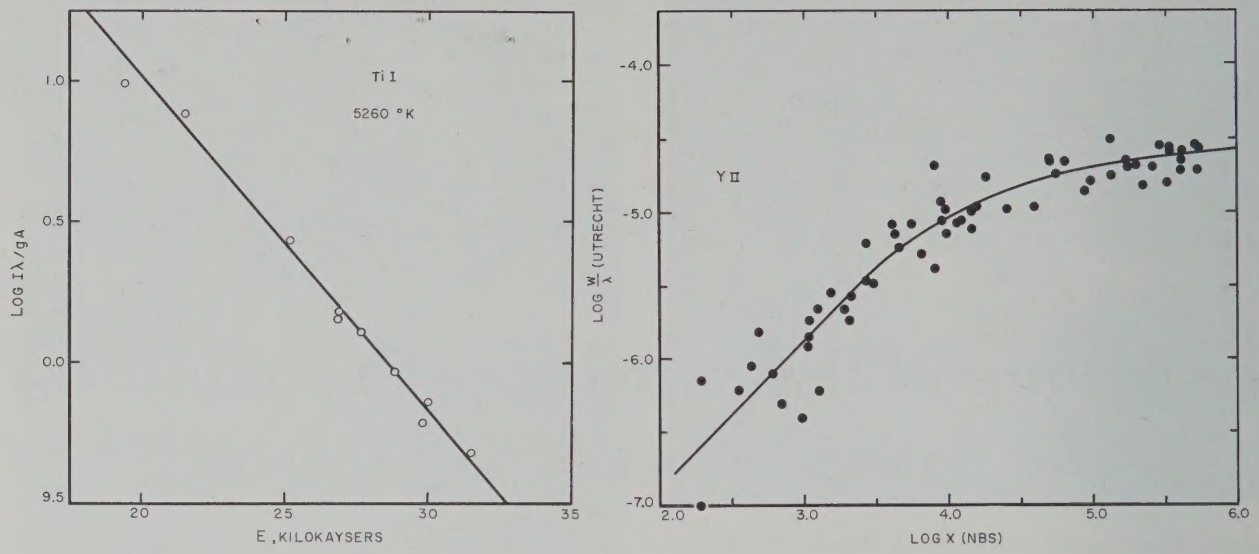
Wavelength and intensity are the primary attributes of a spectral line as observed in the laboratory. The wavelength is ordinarily measured to six significant figures, and occasionally to eight or nine. The intensity, on the other hand, is seldom measured accurately to one figure and never to more than two.

About 30 years ago, W. F. Meggers initiated at the Bureau an extensive program of intensity measurements intended to correct this situation. The light source used to produce the spectra that were measured was a 10-amp, 220-v d-c arc between copper electrodes mounted in water-cooled clamps. The electrodes contained one atom of the element under investigation for every 1000 atoms of copper. The results of this program were recently published as *Tables of Spectral-Line Intensities.*[2] These tables list the principal lines of the 70 elements generally observed under ordinary conditions in arc spectra, together with their relative intensities on a true scale of relative energy. For classified lines, the numerical values of the energy levels between which the transition occurs are also given.

In a determination of the accuracy of the NBS results, comparisons of these intensities were made with published transition probabilities. It became evident from these comparisons that useful transition probabilities could be derived from the intensity measurements. In view of the often stated dissatisfaction of plasma physicists and astronomers with the quantity and quality of available transition probabilities, a decision was made to investigate carefully the possibilities for the conversion of the intensity measurements into transition probabilities.



C. H. Corliss measures the transmission of lines on a spectrogram with a recording microphotometer. These measurements provided calibrations for the derivation of the NBS experimental transition probabilities for spectral lines of 70 elements.



Left: **The arc temperature used in the Bureau's calculations of experimental transition probabilities was obtained from such plots as this for titanium I. The ratio of the spectral-line intensity (obtained previously at the Bureau) times wavelength to published transition probability is plotted versus upper excitation potential for spectra of 20 elements. The linearity of such plots established that the excitation in the arc is described by Boltzmann's Law.** *Right:* **This curve of growth for the second spectrum of yttrium in the sun was constructed using the experimental transition probabilities derived at the Bureau. Such a curve represents the absorption of solar radiation in spectral lines of an element in the solar atmosphere. Ordinate values were taken from the *Utrecht Preliminary Photometric Catalogue of Fraunhofer Lines* (1960); W is the equivalent line width. (A line having an equivalent width of 1 A has absorbed an amount of radiation equivalent to that contained in 1 A of the continuous spectrum at that wavelength.) Abscissae are from the NBS transition probabilities with $X=gf\lambda e^{-E/kT}$ for about 65 unblended lines of Y II between 3100 and 7900 A; here, E is the lower energy and T is the boundary temperature of the solar atmosphere, taken as 4900 °K. The axis of log X has not been normalized to the absolute scale of gf.**

This conversion requires first of all an accurate value of the effective temperature of the arc. The arc temperature was obtained by plotting the ratio of the line intensities to published transition probabilities versus upper excitation potential for spectra of 20 elements. Comparisons made with 31 sets of relative transition probabilities for 1650 lines, obtained from the literature, yielded an average value for the arc temperature of 5100 °K with the standard deviation of the mean of about 2 percent.[3]

With the aid of this arc temperature, it is possible to derive relative transition probabilities from the intensities of the lines of any particular spectrum. In order to express the relative transition probabilities of both the first and the second spectra of an element on the same scale, one must know the degree of ionization in the radiating gas in the arc stream. This was found from the NBS intensities and known absolute transition probabilities for arc and spark lines of 11 elements. The electron density was determined from this information by using Saha's equation, and the degree of ionization for the remaining 59 elements was then computed.[4]

Even though all 70 elements are introduced into the arc at the same rate, the heavy elements will diffuse out of the arc more slowly than the light elements, and the spectral-line intensities will vary accordingly. A correction was made for this variable persistence of atoms in the arc stream so that the relative transition probabilities derived from the intensities are on a uniform scale for all elements. With this variable persistence and the temperature and ionization values, relative transition probabilities are calculated on a uniform scale for the classified lines of atoms or ions listed in the *Tables of Spectral-Line Intensities*. The scale of these relative values can be calibrated against known absolute transition probabilities, and a normalization factor can be determined for every observed line for which an absolute transition probability is known.

The accuracy of the transition probabilities can be considered from two standpoints: as relative values within a single spectrum, or as absolute values. For relative values within a spectrum, the uncertainty in the transition probability depends only on the uncertainties in the temperature and intensity of the line. In the case of absolute values, the uncertainty depends also on uncertainties in the values of electron density, partition functions, and normalization factor. A careful analysis of these component errors indicates a standard deviation of individual determinations of $\log_{10}gf$ equal to 0.2 when taken as relative values in a single spectrum, and to 0.3 when taken as absolute values.

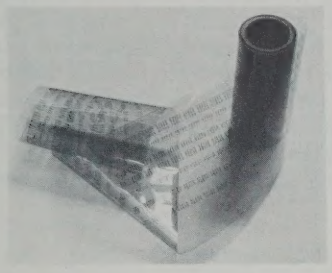
The results are arranged alphabetically by spectrum symbol and by wavelength within each spectrum. Listed are the wavelength in angstroms, the two energy levels to the nearest kayser (cm^{-1}), gA (transition probability) in units of 10^8/sec, gf (oscillator strength), and $\log_{10} gf$.

[1] Experimental transition probabilities for spectral lines of seventy elements, *by C. H. Corliss and W. R. Bozman, NBS Mono. 53 (1962). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., $4.25.*

[2] Tables of spectral-line intensities, *by William F. Meggers, Charles H. Corliss, and Bourdon F. Scribner, NBS Mono. 32 (1961). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Part I $4.00; Part II $3.00.*

[3] Temperature of a copper arc, *by Charles H. Corliss, J. Research NBS* **66A** *(Phys. & Chem.), No. 1, 5 (1962).*

[4] Ionization in the plasma of a copper arc, *by Charles H. Corliss, J. Research NBS* **66A** *(Phys. & Chem.), No. 2, 169 (1962).*



PHOTOCOMPOSITION by Computer Program

Gives High-Quality Typography Semiautomatically

A COMPUTER PROGRAM developed at the Bureau has made possible automatic composition of the extensive, new NBS tables of transition probabilities.[1] This program causes the computer to produce a magnetic tape written in the proper form to operate a photocomposition machine. The machine produces film positives from which printing plates can be made.

W. R. Bozman of the Bureau's spectroscopy laboratory originated and wrote the program expressly for the new tables, but a program of this type could be used to print any repetitive type of literal, numerical, or symbolic output, including, for example, mathematical symbols, subscripts, and superscripts. This method of preparing computer output for publication combines the advantages of automatic operation with the typographical qualities of conventional typesetting.

In recent years, the direct numerical print-outs of automatic computers sometimes have been published to avoid the possible introduction of errors when these outputs are handset in type. This method also has been used simply as an expedient because it eliminates much tedious checking, and the print-outs may be reproduced by various rapid procedures. However, since only a limited number of letters and symbols are available for the direct print-outs, they are not comparable in appearance with typeset material. Also, they often cannot be reproduced evenly and clearly.

The final published material obtained using the Bureau's method is of a quality comparable with that of hand-typeset material. The time required for preparation of data for printing is decreased by approximately 50 percent, resulting in lower cost.

The basic input data for this particular program were available on punched cards, which had been used for preparation of the NBS *Tables of Spectral-Line Intensities*.[2] These data were copied onto a magnetic tape; other parameters and equations required in the calculations of transition probabilities from these data were punched into cards. The tape and cards were the initial computer input.

The initial computer output was a magnetic tape giving transition probability values for lines of the first and second spectra of 70 elements. This tape became the final computer input along with column headings for the tabular material and instructions telling the computer to convert the data tape characters to characters of a form acceptable to the photocomposition machine.

The final computer output was a binary magnetic tape containing the desired headings and tabular material expressed in characters that would operate the

Above: **One of the rolls of 8-in. wide photographic film positive from which printing plates were made for the NBS tables of experimental transition probabilities. The positives were produced on a photocomposition machine controlled by a magnetic tape output from an NBS computer program. Although written expressly for these tables, this type of program may be used to obtain various forms of output.** *Below:* **Example of final published material obtained using the computer program developed at the Bureau to operate a photocomposition machine.**

Wavelength A	Spectrum	Energy Levels K	gA	gf 10^8/sec	Log gf
2702.63	Ba I	0 – 36990	0.92	0.10	−1.00
3071.58	Ba I	0 – 32547	1.8	0.25	−0.60
3501.11	Ba I	0 – 28554	1.8	0.34	−0.47

W. R. Bozman stands at the console of the automatic digital computer on which his program is being run to produce a magnetic tape that will operate a photocomposition machine. This particular output tape is designed for the NBS tables of transition probabilities, but this type of program may be used to obtain various forms of output.

photocomposition machine. This machine was developed by the Mergenthaler Linotype Co. and the IBM Watson Research Laboratory for use in a language translation project sponsored by the Air Force, and had not previously been utilized to obtain a numerical type of output.

With the binary magnetic tape as input, the photocomposition machine produced an 8-in. wide photographic film positive from which printing plates were made. These plates were then used to print the tables of the Bureau's publication on experimental transition probabilities.

A similar, standard production model of the photocomposition machine is operated by punched paper tape, which is made by an operator using a keyboard. This form is best for input of nonrepetitive material. A magnetic-to-paper tape converter has become available since Mr. Bozman's program was written, so that at present his magnetic tape of the tables could be converted to a punched paper tape and run on a standard machine.

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[1] Experimental transition probabilities for spectral lines of seventy elements, *by C. H. Corliss and W. R. Bozman, NBS Mono. 53 (1962). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., $4.25.*

[2] Tables of spectral-line intensities, *by William F. Meggers, Charles H. Corliss, and Bourdon F. Scribner, NBS Mono. 32 (1961). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Part I $4.00; Part II $3.00.*

Mercury 198 Lines as Secondary Length Standards

Victor Kaufman alines part of the optical system used in the interferometric measurement of spectral lines suitable for use as secondary length standards. The mercury 198 electrodeless lamp source is at the far right and is reflected in the mirror at the center; the krypton 86 lamp is behind the mercury lamp.

AN INTENSIVE investigation of the spectrum of mercury 198 was recently undertaken by Victor Kaufman [1] to assist the International Committee on Weights and Measures in selecting secondary wavelength standards for interferometric measurement of length. The vacuum wavelengths of most of the stronger lines of mercury 198 and of several easily resolved krypton 86 lines were measured relative to the international standard of length—the Kr^{86} line at 6057.80211 A—by photographic interferometry. Several of these wavelengths were then selected for presentation to the Committee.

The Eleventh General Conference of Weights and Measures (Paris, 1960) adopted a resolution which stated, in part, "The Meter is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the $^2p_{10}$ and $^5d_5$ levels of the atom of krypton 86." Other resolutions requested the International Committee on Weights and Measures "to establish instructions for putting the new Definition of the Meter into practice" and "to select some secondary wavelength standards for interferometric measurement of length and to establish instructions for their use."

There have been a number of recent investigations of the shifts of the Kr^{86} line as emitted by the hot-cathode discharge lamp as a function of pressure, current density, temperature, and direction of viewing. These studies have gone so far toward answering the first of these requests that the International Committee has recommended use of the hot-cathode discharge lamp operated under specified conditions. The second request, however, has not as yet been met.

A number of the lines emitted by a Hg^{198} water-cooled electrodeless discharge lamp are suitable for use as interferometric length standards. Although none of these has actually been adopted as a standard, the lamp has been used as a convenient source for interferometric length measurements by many laboratories during the past few years. Since this practice is expected to continue, a good set of values for the stronger lines of the spectrum is necessary to provide a firm, consistent basis for measurement.

In the past, measurements have been made of the Hg^{198} lines with respect to the cadmium red line, the former primary wavelength standard. A number of measurements have also been made of a number of the visible Hg^{198} lines with respect to the new Kr^{86} length standard. However, no comprehensive measurement of the Hg^{198} spectrum with respect to the new length standard has previously been reported.

In the present investigation, measurements were made of the wavelengths of 27 Hg^{198} lines emitted from electrodeless lamps containing small amounts of the isotope and argon at pressures of ¼, 3, and 10 mm Hg. These values were used in calculating three sets of energy levels, internally consistent sets of wavelengths, and the wavelength shift per unit pressure of argon for each line. The wavelengths of six lines emitted by Kr^{86} were also measured.

The lines of the Hg^{198} spectrum selected for consideration as standards are at 2537 A, 2652 A, 2753 A, 2894 A, 2968 A, 3022 A, 3126 A, 3342 A, 3651 A, 4047 A, 4359 A, 5462 A, and 5771 A. This group of 13 lines completely covers the region from the photographic ultraviolet to the yellow portion of the spectrum. Each is sufficiently separated from other lines in the spectrum so that with moderate dispersion there will be no problem of measurement error due to neighboring lines. With the exception of those at 2652 A, 2753 A, 2894 A, 3022 A, and 5771 A, the lines are intense enough for the photographic production of interference patterns within 1 or 2 min of exposure. Path differences of up to 300 mm are possible with all except the 2537 A intercombination line.

Interference at much longer path differences can be achieved with the 2537 A line, however, with the use of atomic beam and Zeeman filter techniques. The width of this line is considerably narrower than that of the Kr^{86} standard line. Its wavelength relative to the standard has been determined by other NBS investigators and will also be presented to the International Committee. All three measurements were made with respect to the Kr^{86} primary standard.

It was found that the Kr^{86} lines at 5651 A and 5995 A would also make excellent standards. These lines are of almost the same intensity as the international standard, and could prove very useful for finding the correct orders of interference and hence the proper path difference between interfering rays. This information would aid in the interferometric determination of, for example, other wavelengths and gage-block lengths.

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[1] *For further details, see* Wavelengths, energy levels, and pressure shifts in mercury 198, *by Victor Kaufman, J. Opt. Soc. Am.* **52,** *No. 8, 866 (1962).*

Calculated Germanium Vacuum Ultraviolet Wavelength Standards

CALCULATED wavelength standards in the vacuum ultraviolet region—where very few standards exist—have been increased in number and improved in accuracy as the result of an extensive cooperative effort [1] by the Bureau and Purdue University. This study, by Victor Kaufman of NBS and K. L. Andrew of Purdue, extended the interferometric region of measurement of neutral germanium (Ge I) lines (formerly 2019 to 4685 A) to 12069 A. A number of lines of singly ionized germanium (Ge II) were also measured interferometrically. This work was partially supported by a grant of the National Science Foundation.

Because vacuum ultraviolet spectra are difficult to produce and resolve satisfactorily with available equipment, there is a lack of reliable vacuum ultraviolet wavelength standards. Therefore work in this portion of the spectrum is at present seriously curtailed. As a result, considerable uncertainty exists in the identification of many solar spectrum lines. Proper identification of these lines will be of great value to astrophysicists seeking a better understanding of the basic energetic and hydrodynamic relationships on the sun.

The task of expanding the present range of germanium vacuum ultraviolet standards originated

Use of a photoelectric scanning comparator designed and constructed at the Bureau greatly decreases the time required for measurement of spectrographic plates. Victor Kaufman uses such a comparator to measure interferograms of germanium lines for the precise determination of their wavelengths.

with Kaufman and Andrew at Purdue. Since one of the basic responsibilities of NBS is the establishment and maintenance of standards, the research was continued jointly after Kaufman joined the Bureau staff. A systematic program of interferometric wavelength determinations was carried out for the lines of Ge I from 4380 to 12069 A in an effort to improve the accuracy of previously determined Ge I vacuum ultraviolet Ritz standards and to increase the number of these standards.

Ritz standards are so named because they are calculated using the Ritz combination principle. This principle states that, with certain limitations, the difference between any two energy levels of an atom gives the wave number of a spectral line of the atom. Thus, the wave number (reciprocal of the wavelength *in vacuo*) of any spectral line can be calculated if the energy levels involved in the transition are well known.

The interferometric measurements were made in the visible and infrared portions of the spectrum for a number of reasons. First of all, it is not at present possible to use an interferometer in the vacuum ultraviolet portion of the spectrum. Secondly, when direct measurements of lines at shorter wavelengths are made using presently available techniques, the wavelength values obtained are not so accurate as those that can be calculated on the basis of interferometric measurements of lines at longer wavelengths. Also, there are very few standards with which to measure vacuum ultraviolet lines. In the vacuum ultraviolet portion of the spectrum, then, it is preferable to calculate the desired wavelength using energy level values determined from measurements in the visible and infrared portions of the spectrum.

The improvement in energy levels desired for the present work was achieved by combining the wavelength values obtained from this study and those of Humphreys and Paul [2] in the region 11255 to 19284 A with those in the region 2019 to 4685 A obtained from previous investigations.[3] These values were used in conjunction with the Ritz combination principle to calculate vacuum ultraviolet wavelengths to a high degree of accuracy for use as standards.

In this way, the total number of calculated Ge I standards below 2000 A with uncertainties estimated to be within 0.0008 A has been increased to about 100 lines. The uncertainties of about 70 of these should be within 0.0003 A. The measurements of Ge II lines made possible the calculation of 12 additional vacuum ultraviolet standards in the range from 999 to 1966 A.

An experimental study [4] of these Ge I lines in the vacuum ultraviolet shows, however, that not all are satisfactory for use as secondary wavelength standards. The choice of lines to serve as secondary standards is based on such characteristics as intensity, sharpness, and separation from neighboring lines.

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[1] Germanium vacuum ultraviolet Ritz standards, *by Victor Kaufman and Kenneth L. Andrew, J. Opt. Soc. Am. (In press).*

[2] *C. J. Humphreys and E. Paul, Jr., NOLC Corona, Quarterly Report (Oct.–Dec. 1961).*

[3] *R. D. VanVeld and K. W. Meissner, J. Opt. Soc. Am.* **46,** *598 (1956).*

[4] *K. W. Meissner, R. D. VanVeld, and P. G. Wilkinson, J. Opt. Soc. Am.* **48,** *1001 (1958).*

NBS Hydrocarbon Standard Materials Transferred to American Petroleum Institute

Effective October 1, 1962, the American Petroleum Institute assumed responsibility for the distribution of hydrocarbon and sulfur standard samples to all users. Previously, API had issued such standards to the petroleum industry, while the Bureau had supplied laboratories not associated with the petroleum industry. Orders for these samples have not been accepted by NBS since September 1, 1962.

A total of about 174 specific compounds [1] were transferred from the Bureau to the API Samples Office at Carnegie Institute of Technology. Eleven groups of chemicals—paraffins, alkyl cyclopentanes, alkyl cyclohexanes, monoolefins, diolefins, cyclomonoolefins, acetylenes, alkyl benzenes, naphthalenes, polycyclic hydrocarbons, and organic sulfur compounds—will be included in the transfer. These

standards are issued primarily for calibrating instruments and apparatus in the research, development, and analytical laboratories of the petroleum, rubber, chemical, and allied industries.

The services offered by the Institute are essentially those formerly provided by the Bureau. Requests for information concerning the program and procedures for purchasing the standard samples should be addressed to

Carnegie Institute of Technology,
Attention: Beveridge J. Mair,
Petroleum Research Laboratory,
Pittsburgh 13, Pennsylvania.

The API has available 341 compounds as Standard Samples. These include 294 hydrocarbons, 38 organic sulfur compounds and 9 organic nitrogen compounds.

In general, the development of the hydrocarbon program is an excellent example of cooperative effort on the part of industry and Government to prepare improved standards for physical measurements. Early in 1943, the Petroleum Industry War Council requested the Bureau to include hydrocarbons of high purity in its standard sample program. Under the direction of Frederick D. Rossini,[2] former chief of the NBS thermochemistry and hydrocarbon laboratory, about 15 hydrocarbons were completed within the year. However, the needs of the industry for new hydrocarbon standards increased so rapidly that a greater rate of production was necessary. Therefore, the American Petroleum Institute was requested to cooperate so that all the facilities of the Institute's existing research projects could be utilized. In 1950, part of the stock of standard hydrocarbons at the Bureau was transferred to API Samples Office at Carnegie Institute of Technology. API filled orders from laboratories associated with the petroleum industry whereas the Bureau continued to supply laboratories not directly related to the petroleum industry. The Bureau has been distributing about 100 hydrocarbon standards per month.

Eight hydrocarbon blends, NBS Standard Sample Nos. 592 to 599, and three hydrocarbons certified for density and refractive index, NBS Standard Sample Nos. 211, 217, 218, may still be purchased directly from the Bureau.[3] The blends are primarily intended for calibrating mass spectrometric and other instrumental procedures employed in the analysis of gasolines, naphthas, and blending stocks, whereas the three latter standards may be used to calibrate refractometers, picnometers, and density balances, as well as spectrometers.

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[1] *The standards involved in the transfer are listed in Section 3.2.6, Hydrocarbons and Organic Sulfur Compounds, pp. 10–14 of* Standard Materials, *NBS Misc. Publ. 241. This publication may be ordered for 30 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Up-to-date supplementary inserts, which are issued periodically, are available upon request directly from the National Bureau of Standards.*

[2] *Now Dean of the College of Science, University of Notre Dame, Notre Dame, Indiana.*

[3] *The materials are described in* Standard Materials, *NBS Misc Publ. 241. A total of over 500 different standard materials are available from the Bureau—principally chemicals, ceramics, metals, ores, and radioactive nuclides.*

Electron-Optical Image of a Pulsed Atomic Beam

STROBOSCOPIC pictures of rarefied atomic beam packets resolved in flight with an effective shutter speed of 1 μsec have been obtained at the Bureau. The pictures were produced using a pilot instrument built during a gas dynamics study conducted by L. Marton, S. R. Mielczarek, and D. C. Shubert of the electron physics laboratory. The objective of this work, sponsored by the Office of Naval Research, was the development of a method [1] for determining instantaneous spatial distributions of chopped atomic beams in flight and for translation of this information into vector velocity distributions.

It is expected that future investigators will be able to utilize the Bureau's technique in systems operating at a higher vacuum than is obtainable at present. Such conditions will permit measurement of velocity distributions in pulsed beams which have been reflected from solid targets. With this information, one can compute the thermal accommodation and viscous slip coefficients for interactions between solid objects and streams of rarefied gases. These coefficients determine the heating and drag effects of the upper atmosphere upon missiles and satellites. In addition, they constitute the boundary conditions at the surfaces of models in wind tunnel studies. Proper interpretation of wind tunnel data is at present greatly hampered by the lack of reliable estimates for the values of these coefficients.

The instrumentation [1, 2] developed during the Bureau study is an electron-optical analog of the dark-field schlieren method of observation, which is used extensively in wind tunnels and in shock-tube studies. In conventional dark-field schlieren experiments, a light

beam is brought to a focus on a small round stop. Small deflections of the light beam as it passes through the medium cause some of the light to miss the stop, and this light proceeds to a photographic plate. Since the deflections are the result of density gradients in the liquid or gas which cause corresponding gradients in optical index of refraction, a photographic image is formed in which the light intensity is roughly proportional to the magnitude of the density gradient. Unfortunately, when this method is applied to gas systems operated at progressively lower pressures, the gradients in refractive index approach zero and the required optical systems become increasingly critical. In the neighborhood of 0.1 mm Hg pressure, the method becomes altogether unworkable.

In the Bureau's method, the light beam is replaced by an electron beam, and some of the electrons are scattered, through angles sufficient to miss the stop, by collisions with individual gas atoms in the atomic beam. Since the electric field gradients within individual atoms are essentially independent of atomic concentration, the electron scattering angles remain appreciable, and the optical system remains noncritical at the lowest attainable pressures.

In the present apparatus, the electron beam passes through a ribbon-shaped atomic beam, and the image is formed by electrons scattered through angles between 0.005 and 0.015 rad. The cross-sectional dimensions of the atomic beam are 25 mm by 1 mm. The effective scattering cross section under these conditions is approximately 2×10^{-17} cm^2, and continuous (unpulsed) beams with densities equivalent to pressures between 10^{-7} and 10^{-4} mm Hg are photographed with exposures ranging from 1 to 10 sec. A comparable experiment using light-optical schlieren detection with the same range of deflection angles would require an atomic beam about 100 km wide. Most of the atomic beams photographed with the present apparatus were composed of cadmium vapor, but the method is equally applicable to other vapors and to the permanent gases. Air and CO_2 molecular beams have been successfully photographed.

When the apparatus is operated stroboscopically, a series of moving atomic beam packets is generated by means of a conventional pair of rotating slotted disks. The exploring electron beam is limited to pulses of such short time duration (1 to 3 μsec) that atomic travel during the pulse is less than 1 mm, and succeeding

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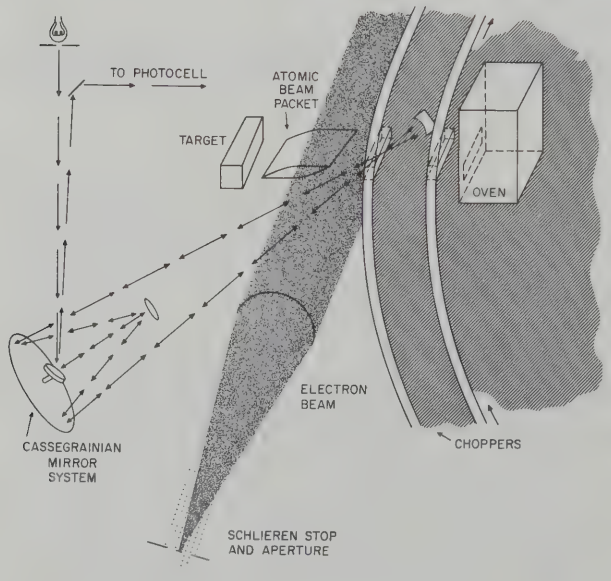
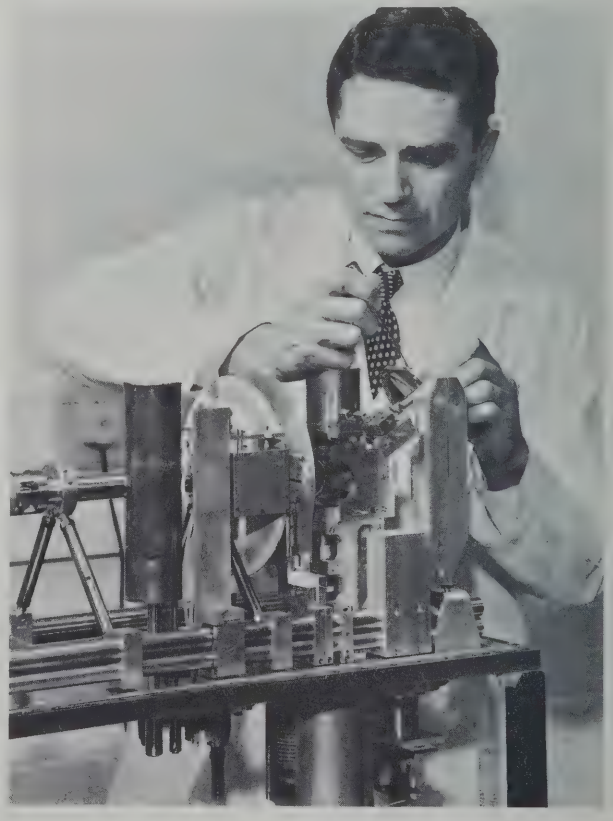
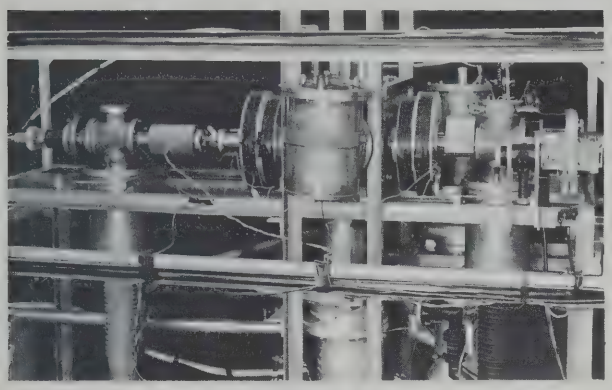
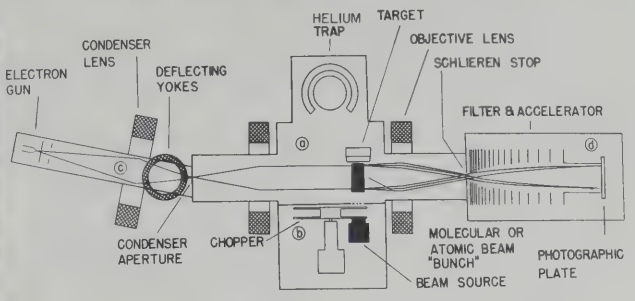
Left: **Beam-interaction section of the apparatus. In this section, a series of moving atomic beam packets is generated by means of a pair of rotating slotted disks; each packet interacts with the corresponding electron pulse and proceeds to a target. The arrows indicate the path of a light beam used to synchronize the chopping disks, the atomic beam pulse, and the electron pulse, so that the timing accuracy is independent of vibration of the chopping disk assembly and of errors in spacing of the radial slits in the disks.** *Right:* **D. C. Schubert adjusts one of the mirrors of the optical system of a pilot instrument developed for obtaining instantaneous spatial distributions of chopped atomic beams. The apparatus is shown in an inverted position during assembly. The slotted chopping disks are at the left; behind them is the oven in which the material in the atomic beam (usually cadmium) is vaporized. At lower right are the target and part of the optics used to synchronize the beams and the chopping disks.**





Left: **Outside view of pilot instrument containing electron-optical schlieren system for determining instantaneous spatial distributions of chopped atomic beams in flight.** *Right:* **Schematic diagram of instruments.**





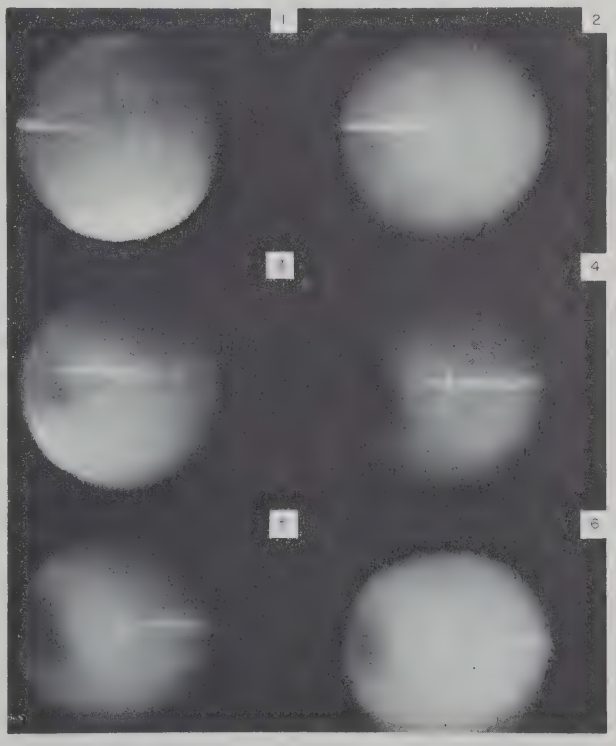
DARK FIELD SCHLIEREN TECHNIQUE

electron beam pulses are timed with respect to the corresponding atomic beam pulses so that each electron beam pulse "sees" the atomic beam pulse in the same position. A synchronizing electrical signal for this purpose is obtained from a light beam fed into a photomultiplier. The light beam first, however, passes through the same chopper slit which is transmitting the atomic beam. In this way, the timing accuracy becomes independent of vibrations of the chopper disk assembly and of errors in the spacing of the radial slits. The light source and the detector are located outside the vacuum chamber, and mirror optics are used exclusively for the light beam within the chamber.

The image of the pulsed atomic beam appears against a background provided by the gas molecules remaining in the vacuum system. For adequate contrast, the density of atoms in the atomic beam packet must be an order of magnitude greater than the density of background molecules. The most intense chopped atomic beam packets produced have densities equivalent to about 10^{-6} mm Hg pressure. A background vacuum of 5×10^{-8} mm Hg is obtained using cryogenic pumping with a liquid hydrogen Dewar. Provision is made for baking the system at about 300 °C to improve this vacuum by another order of magnitude.

The pulsed electron beam pictures are recorded on photographic plates, and the resulting photographic density distributions are measured with a double-beam microdensitometer. The typical ratio of the densities of beam image to rms background fluctuations for 0.1 mm resolution on the plates is better than 10:1. The image recorded on the plates is about 1.7 cm in diameter. An extremely large amount of time-resolved information therefore can be gathered and stored on a single plate. In contrast with the point-by-point approach of conventional atomic beam measurements, all the velocity distribution data are quickly gathered under a given set of conditions and retained as permanent compact records. This feature greatly reduces the probability that a dismantled experimental setup may have to be reconstructed because of a need for more data points that could not have been anticipated during the original run.

A method for converting the spatial distribution of atoms reflected from a target into the velocity distribution of reflected atoms has been worked out. Spatial distributions of reflected atoms are obtained by pulsing the electron beam at a suitable time after the arrival of the atoms at the target. In this case, the photographic image becomes a measure of the instantaneous density of reflected atoms. If all the atoms had arrived simultaneously at a single point on the target, this image could be interpreted directly as the velocity distribution of the reflected atoms. Such a distribution is assumed as a first approximation to the true distribution. Then the spread in arrival times and positions



Time-resolved electron-optical images of a pulsed atomic beam in flight. Time interval between successive images is 15 μsec. The images are used in the determination of instantaneous spatial distributions of chopped atomic beams in flight. These can then be translated into vector velocity distributions.

on the target, as calculated from the geometry of the source and the chopper slits, is used in an integration process to obtain a correction to the velocity distribution. This process may be repeated successively, using the last approximation each time as a basis for computing a correcting term, until the resulting corrections become negligible.

Thus, in velocity distribution studies one could use an incident atomic beam packet with dimensions that are appreciable in comparison with the size of the field of view. Without this relatively large incident beam pulse, it would be impossible to attain a reasonable ratio between the density of atoms in the reflected beam and that of atoms in the background vacuum. In the present apparatus the mean density of atoms in a reflected beam corresponds to a pressure of 2×10^{-8} mm Hg; thus a background vacuum of about 10^{-9} mm would be needed for useful measurements of velocity distributions of reflected atoms.

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[1] A method for the study of vector velocity distribution of low density molecular beams, *by L. Marton, S. R. Mielczarek, and D. C. Schubert, Rarefied Gas Dynamics (ed. L. Talbot), Academic Press (New York, 1961).*

[2] Electron-optical study of low-density gas flow, *NBS Tech. News Bull.* **41**, *No. 10, 158–160 (1957).*

NBS Holds Seminar on Mass Measurement

THE MASS AND SCALE Section sponsored a seminar on mass measurement at the Bureau on June 21, 1962. Purpose of the meeting was to review the areas of responsibility relative to NBS calibration services that are essential to accuracy at the measurement level; to describe experimental work undertaken to improve balance performance and weighing accuracy; and to discuss measurement problems of concern both to the manufacturer and to the laboratory user of measuring equipment, as well as to the Bureau. In attendance were over 50 representatives of the scientific apparatus industry and of the various standardization laboratories in this country.

R. D. Huntoon, Deputy Director of the Bureau, welcomed the conferees in an opening address. He stressed the role of the Bureau in performing basic research directed toward developing independently reproducible units for all physical constants, including mass. Presiding at the morning session was James C. Jacobson, president of the Voland Corp., New Rochelle, N.Y.

In introductory remarks, Paul E. Pontius, Chief of the Mass and Scale Section, pointed out that every mass measurement has its own particular accuracy requirement, and that several factors must be taken into consideration with regard to this requirement. These factors are the performance of the equipment, the experience of the operator, the weighing procedure, and the reliability of the reference standard employed. The Bureau is responsible for calibrating reference mass standards in terms of the national prototype standard of mass; those who use the standards are responsible for transferring the accuracy inherent in the national standards to meet the needs of science, industry, and commerce.

Mr. Pontius also developed mathematical formulas to show the cumulative effects of various systematic and random errors that may occur in the performance of balances. He illustrated how the formulas apply to certain types of balance design and configuration.

H. A. Bowman of NBS presented a paper on the major arrestment errors associated with the coupling between the suspension and the beam. He showed data, taken on the NBS experimental 1-kg balance, in which these sources of uncertainty were reduced to a few parts in 10^9. This was accomplished by a novel arrestment design (in which knives and flats were maintained at a constant load throughout the entire arrestment and weighing cycle) and by a multiple link suspension.

Lee Cahn, president of the Cahn Instrument Co., Paramount, Calif., described the effects of aerodynamic disturbances on a new 2½-g electrobalance, and methods for achieving reproducibility with this balance. It may be used for making measurements in vacuum, in reduced atmospheres, and in a normal atmosphere.

Lloyd B. Macurdy, recently retired from the Bureau, reported in the final morning paper on investigations made at the Bureau on thermal gradient effects with regard to mass measurements. He described the violent and erratic changes that occur in the indication of a balance at near isothermal conditions and when the top of the balance case is cooler than the bottom. He also described experiments with several configurations of insulation which provided appreciable control of thermal disturbances, and suggested practical methods for minimizing these troublesome effects.

Herbert K. Alber, Director of Research and Development for the Arthur H. Thomas Co., Philadelphia, Pa., was chairman of the afternoon session. H. Haig Russell, in charge of the large-scale testing program of the Bureau, talked at this session on derived mass values for weights and other objects. He stated that the validity of such values cannot be established without proper documentation of every calibration or test procedure performed in a standardization laboratory. He said that this documentation should include the date of calibration or test, name of operator, identification of the reference standard used as to its calibration or test, and a detailed record of the observations and computations made. Thus a record is obtained and preserved which, when audited, will disclose the adequacy of equipment and procedures used and will therefore constitute evidence of the validity of the derived value.

Mr. Pontius then explained the two types of mass calibration that are now available from the Bureau. The first type is called a Scientific Reference Standard Calibration, for which a certificate of calibration is issued. Weights submitted for this calibration must be of one-piece design and meet certain criteria as to fabricating material and surface finish. The second type is called a Laboratory Reference Standard Calibration, for which a test report is issued. Most calibrations fall into this category, since less rigid requirements are imposed.

The final paper of the session was given by Churchill Eisenhart, Chief of the Bureau's statistical engineering laboratory. He discussed factors to be considered in making a realistic evaluation of the precision and accuracy of measurement processes involved in the calibration of mass standards. He reminded the audience that, as used in measurement science, "accuracy" has to do with closeness to the true value of the quantity measured; "precision" only with the closeness together of repeated measurements of the same quantity. He stressed that in evolving an experimental program to determine the precision and accuracy of a particular measurement process it is essential to be clear on exactly what variations of procedure, apparatus, conditions, observers, etc., are allowable in "repeated applications" of what will be considered to be the same measurement process applied to the measurement of the same quantity under the same circumstances.

IRE Microwave Group Symposium

Four hundred and sixty scientists and engineers from government and industry attended the 1962 National Symposium of the Institute of Radio Engineers' Professional Group on Microwave Theory and Techniques, held May 22–24, 1962 at the NBS Boulder Laboratories. In addition to an introductory program, the Symposium included 37 technical papers presented in ten sessions.

The introductory meeting was addressed by Tore N. Anderson, Chairman of the National Professional Group, and G. E. Schafer, Chairman of the Symposium, following a greeting by F. W. Brown, Director of the Boulder Laboratories and host for the sessions of the Symposium. The keynote speech was delivered by J. M. Richardson, Chief of the NBS Radio Standards Laboratory. In it he spoke of the establishment of microwave standards by the Bureau at a time when firm standards in this frequency range were unknown and described the technical developments at NBS which now permit measurement of power at 10 Gc/s to an accuracy of 0.2 percent. Dr. Richardson described the mutual dependence between the microwave engineering profession and NBS in identifying areas needing reliable standards and development of both the new standards and techniques of using them. He hailed the Symposium for bringing together the users and keepers of standards.

The first session, presided over by Donald D. King of Electronic Communications, Inc., dealt with microwave frontiers; it was comprised of papers describing new research on efficient millimeter-wave resonators; the use of low temperatures to reduce attenuation of microwave delay lines to make possible, near absolute zero, delays over 1 msec; and a compact 200-Mc/s ferro-electric phase shifter capable of shifts of 360°.

Papers on the theory of waveguide properties were presented in the second session, of which Anthony A. Oliner of the Polytechnic Institute of Brooklyn was chairman. One paper described the unexpected modes of propagation encountered in simulating the whistler mode of propagation in an overdense bounded magnetoplasma. Others presented experimental results of a method using perturbations of the radiation field to measure absolute field strengths on the boundaries of microwave resonators and demonstrated a generalized method of evaluating attenuation due to finite waveguide wall conductivity.

Session three, also presided over by Prof. Oliner, was devoted to the theory of waveguide discontinuities. Perturbation theorems for waveguide junctions were derived and applications given, a reflection coefficient for small discontinuities at the junction of a sharp-inside-cornered waveguide with rounded-inside-cornered waveguide was given, the diffraction of a plane wave by a planar array of conducting disks described, and a representation proposed for waveguide containing a small ferrimagnetic ellipsoid.

Seymour B. Cohn of the Rantec Corp. was chairman of the fourth session, which was devoted to filters. Designs of bandpass filters using interdigital arrays of resonator line elements between parallel ground planes and of wideband 13-branch couplers for waveguide, coaxial line, and stripline were described. Design formulas were given for narrow bandstop filters having minimal insertion loss outside the stopband and the use of a plasma column in electronically-tunable bandpass filters was discussed.

The fifth session, also under Dr. Cohn, was devoted to high microwave power; it consisted of papers on the measurement of total multimode power by means of many fixed probes in a section of expanded waveguide; the suppression of X-band harmonics by means of a leaky-wall, low-pass filter; the use of alternate absorbent and insulating layers in high-power microwave attenuator-terminations; and the control of interline noise and modulation products in high-power microwave amplifiers.

Session six, presided over by R. W. Beatty of the NBS Boulder Laboratories, was devoted to microwave measurements. It included descriptions of two new measurement devices, a microwave phase comparator having no ambiguities, and a set meas-

Neil Larsen of NBS (*right rear*) explains a detail of the national standard of microwave power to three PGMTT members. The X-band standard (*right*) and the Ku-band standard (*left*) are used to calibrate bolometer mounts used by the NBS Electronic Calibration Center. Development of the Ku-band standard has expanded the upper limit of NBS calibration services from 12.4 to 18 Gc/s.

uring losses to 80 db and envelope delay to 100 nsec in the 50 to 60 Gc/s range. The dilemma in low-noise measurements created by stringent system requirements and lack of accurate noise standards was discussed, and the development of noise standards for L-, S-, and X-band in coaxial line and waveguide and the calibration of gas discharge tubes were described. The use of perturbation techniques was also discussed for determining the microwave transport properties of a semiconductor contained in a waveguide by measurements of the transmitted wave.

The development and refinement of microwave components was discussed in section seven, also under the chairmanship of R. W. Beatty. The improvement in waveguide devices at millimeter wavelengths made possible by new materials and improved techniques was noted, as was the use of ferrites for fast switching at L-band frequencies in both coaxial transission line and stripline. The analysis of dielectric loading of waveguide by use of computers was discussed. The development of a stripline varactor duplexer capable of 6-kw operation at 1.6 Gc/s with transmitter-receiver isolation greater than 40 db also was described.

Session eight was devoted to microwave limiters, under M. T. Lebenbaum of Airborne Instruments Laboratory. It included graphical representation of TEM transmission line bandwidth, controlled diode self-resonance for broadline limiters, yttrium iron garnet crystals in subsidiary resonance milliwatt microwave limiters, and compensation for temperature changes in component characteristics by means of the temperature dependence of the anisotropy field. Anisotropic characteristics were also used in a J-band passive limiter to control threshold levels over 9 db by orientation of an external magnetic field in relation to the crystal. An explanation was presented for experimental results showing limiting by low power passive ferrite limiters in a frequency-by-frequency manner for signals separated by a minimum of about 1 Mc/s, unlike smaller-signal supression in the normal limiter.

Parametric amplifiers were examined in session nine, which was also presided over by M. T. Lebenbaum. The development and experimental use of two or more independent pumps operating at different frequencies was reported, as was the unified design of a circulator and L-band tunnel diode preamplifier providing 15 db gain over a 16 percent bandwidth at 1 db down. Varactors used in parametric amplifiers was the topic of two papers, one giving a technique for broadbanding by use of passbands characteristic of the diode and mount and the other describing hysteresis and switching effects in the operation of nondegenerate varactor parametric amplifiers.

Session ten closed the Symposium with a look into the future of microwaves and solid state devices through the eyes of three invited authorities, under the chairmanship of Kiyo Tomiuasu of General Electric. Frank Barnes of the University of Colorado described the probable use in the future of masers in the millimeter wave region, for both low-noise amplification and for power generation. Benjamin Lax of MIT's Lincoln Laboratory described the opening of many new fields and applications as a result of the interaction between solid state and microwave research, especially those brought about by the advent of the optical maser and discovery of nonlinear phenomena in solid state plasmas. A. Gardner Fox of the Bell Telephone Laboratories foresaw the use of coherent light in communication systems and, for man, an expanding role in store for the microwage engineer.

Many of the papers delivered at this Symposium will be given even wider attention by appearing in the Symposium Issue of the Transactions of the PGMTT (Nov. 1962). This will help attain the goals of the Symposium by furthering communication between the users of microwave standards and the Bureau.

Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Vol. **46**, No. 9, Sept. 1962. 15 cents. Annual subscription: $1.50. 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Basic Radio Propagation Predictions for December 1962. Three months in advance. CRPL–217, issued September 1962. 15 cents. Annual subscription: $1.50, 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards.

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

Current Issues of the Journal of Research

Section A. Physics and Chemistry, Vol. **66A**, No. 5, Sept.–Oct. 1962.

Calorimetric calibration of an ionization chamber for determination of X-ray total beam energy. J. S. Pruitt and S. R. Domen.

Zinc oxide as a standard substance in the solution calorimetry of portland cement. E. S. Newman.

Nuclear optical model analysis of neutron elastic scattering for calcium. R. S. Caswell.

Pyrolysis of some polyvinyl polymers at temperatures up to 1,200 °C. S. Straus and S. L. Madorsky.

Lattice frequencies and rotational barriers for inorganic carbonates and nitrates from low temperature infrared spectroscopy. R. A. Schroeder, C. E. Weir, and E. R. Lippincott.

Foreign gas broadening of the lines of hydrogen chloride and carbon monoxide. E. K. Plyler and R. J. Thibault.

Monolayers of adipate polyesters at air-liquid interfaces. W. M. Lee, R. R. Stromberg, and J. L. Shereshefsky.

Section D. Radio Propagation, Vol. **66D**, No. 5, Sept.–Oct. 1962.

Theory of magneto-telluric fields. J. R. Wait.

Propagation characteristics of magneto-ionic plasma columns. D. Formato and A. Gilardini.

Dielectric loading of electric dipole antennas. J. Galejs.

Possible influence of the ionosphere on the impedance of a ground-based antenna. J. R. Wait.

Some statistical theory for the analysis of radio propagation data. M. M. Siddiqui.

Auroral sporadic-*E* ionization. R. D. Hunsucker and L. Owren.

Comparative study of the correlation of seasonal and diurnal cycles of transhorizon radio transmission loss and surface refractivity. B. R. Bean.

Enhancement of the lunar tide in the noon critical frequency of the F_2 layer over the magnetic equator. R. G. Rastogi.

Scattering from a conducting sphere embedded in a semi-infinite dissipative medium. J. Galejs.

High-frequency scattering from a coated sphere. V. H. Weston and R. Hemenger.

Propagation of spherical waves through an ionosphere containing anisotropic irregularities. K. C. Yeh.

Nonperiodicals

Tables of Einstein functions. Vibrational contributions to the thermodynamic functions, J. Hilsenrath and G. G. Ziegler, NBS Mono. 49 (July 12, 1962), $2.75.

Bibliography on atomic transition probabilities, B. M. Glennon and W. L. Wiese, NBS Mono. 50 (Aug. 1, 1962), 35 cents.

Experimental transition probabilities for spectral lines of seventy elements, C. H. Corliss and W. R. Bozman, NBS Mono. 53 (July 20, 1962), $4.25.

Technical Notes

The sale of NBS Technical Notes has been transferred from the Office of Technical Services, Department of Commerce, to the Superintendent of Documents, U.S. Government Printing Office. All Technical Notes carrying a PB number must be ordered from OTS. All Technical Notes without PB numbers must be ordered from the Superintendent of Documents.

A survey of the techniques for measuring the radio refractive index, R. E. McGavin, NBS Tech. Note 99 (May 1962), 30 cents.

Required signal-to-noise ratios, RF signal power, and bandwidth for multichannel radio communications systems, E. F. Florman and J. J. Tary, NBS Tech. Note 100 (Jan. 1962), $1.00.

A tabulation of the thermodynamic properties of normal hydrogen from low temperatures to 540 °R and from 10 to 1500 psia, Supplement A (British units), J. W. Dean, NBS Tech. Note 120A (June 1962), 45 cents.

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Worldwide patterns of ionospheric blackout occurrence, V. Agy and K. Davies, J. Atmospheric and Terrest. Phys. **23,** 202–205 (Dec. 1961).

Fluorescence and rotational relaxation of OH radicals in flames, T. Carrington, Eighth Symp. (Intern.) on Combustion, pp. 257–262 (The Williams & Wilkins Co., Baltimore, Md., 1960).

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I. Strange sounds in the atmosphere, R. K. Cook, Sound—Its Uses and Control **1,** No. 2, 12–16 (Mar–Apr. 1962).

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